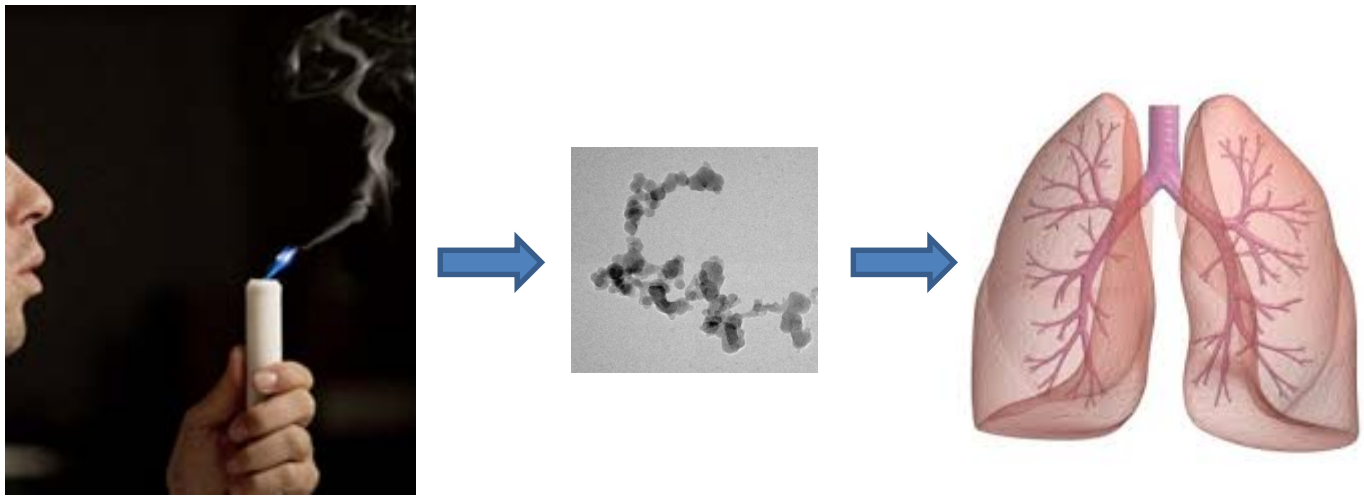
Personal exposure to ultrafine particles and responsible sources



Gabriel Bekö

DTU
International Centre for Indoor Environment and Energy
Department of Civil Engineering
Technical University of Denmark

Size range of airborne particles

Largest particle: 100 µm (10^{-4} m)
Smallest particle: 2 nm (0.002 µm or 10^{-9} m)
5 orders of magnitude

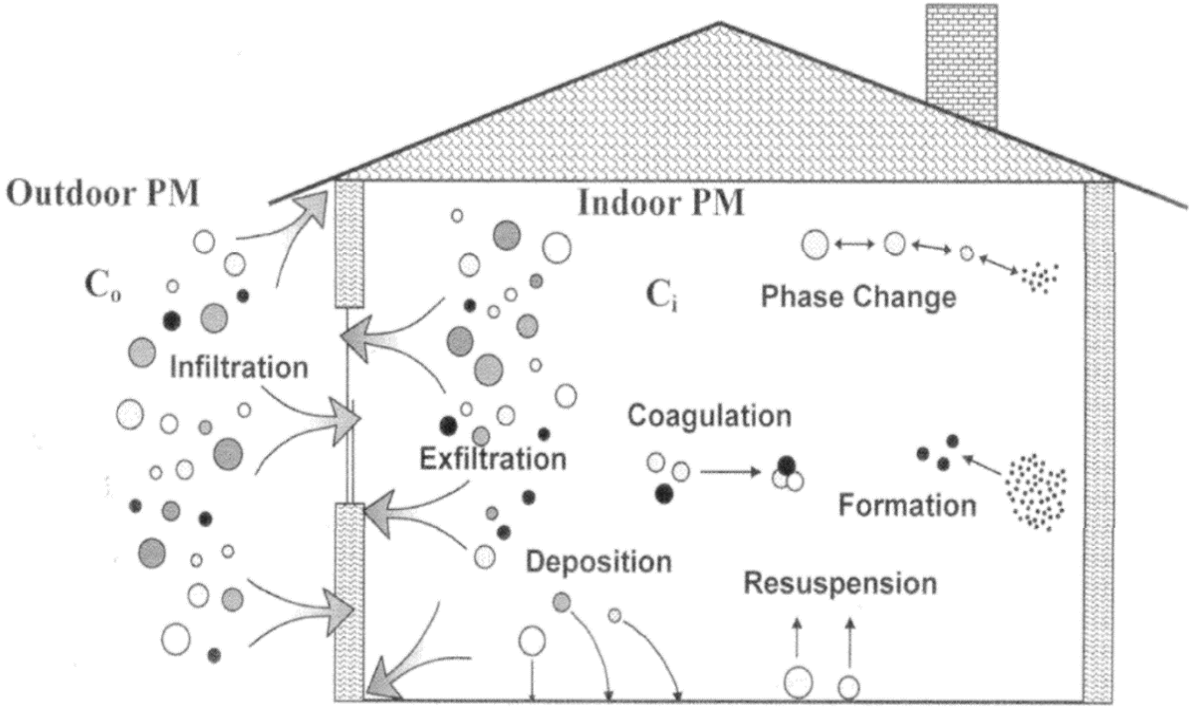
Ultrafine particles: <100nm (0.1 µm)
Fine particles: 0.1 – 2.5 µm (PM2.5)
Coarse particles: >2.5 µm

100 µm

2 nm

Particles indoors

- particles emitted indoors (cooking, smoking, resuspension, textile fibers, skin flakes)
- ambient particles infiltrated indoors
- particles formed indoors through reactions of gas-phase precursors emitted both indoors and outdoors (ozone/terpene reactions; Ozone/skin oil reactions



Thatcher et al. Aerosol Sci Technol, 2003

Humans emit particles

Humans replace their outer skin layer every 2 to 4 weeks

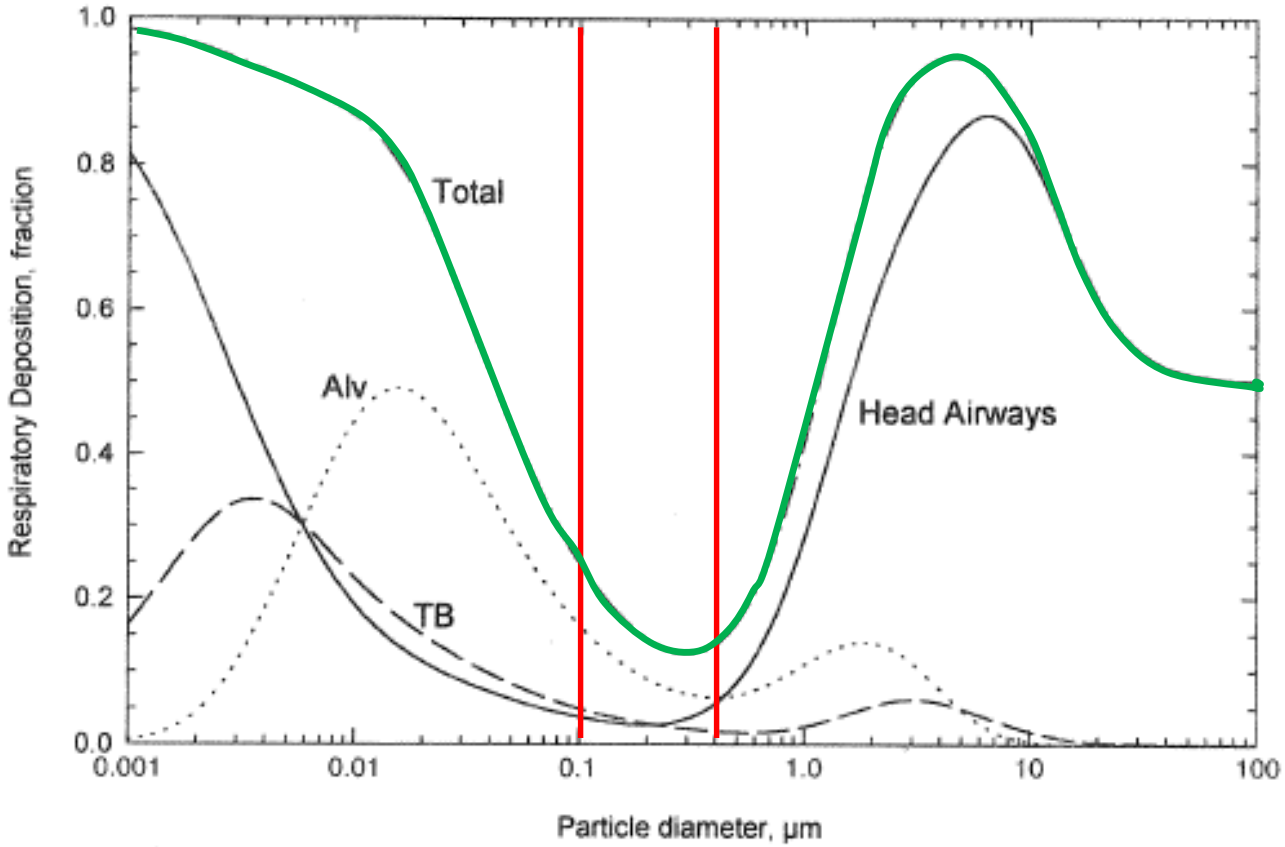
One person emits:

- 200,000 – 600,000 skin flakes/min
- 30 – 90 mg skin flakes/h

Milstone, J Derm Sci, 2004

Deposition model

Most Penetrating Particle Size 0.1 – 0.5 µm



Ultrafines: Able to reach the smaller airways of the lower respiratory tract

Large surface area per unit mass

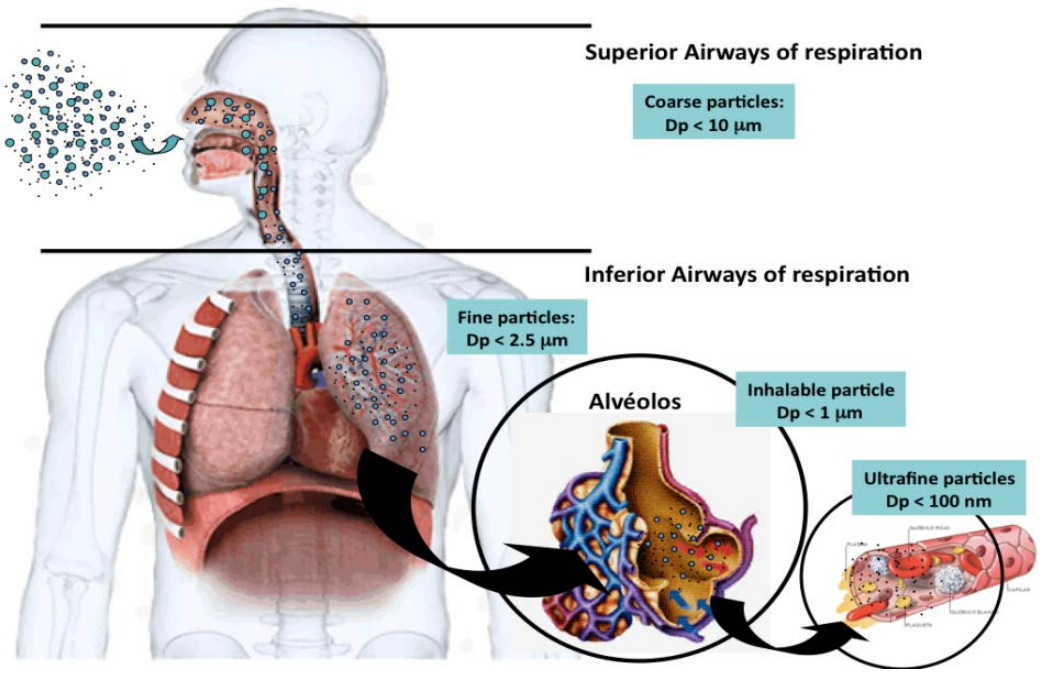
Toxic and carcinogenic substances

- polycyclic aromatic hydrocarbons (PAHs)
- metals

Health Effects

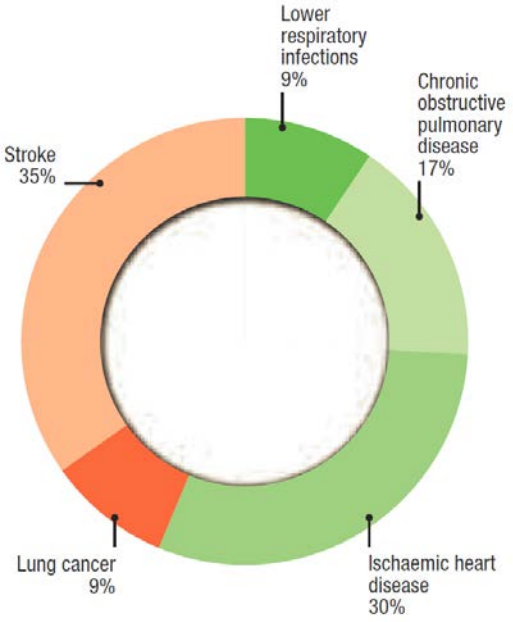
Subjective responses:

- Irritation of eyes, nose, throat
- Dry skin sensation
- Odor and taste symptoms
- Headache
- Fatigue
- Dizziness
- Reduced capability to concentrate
- Reduced productivity



Health effects

- Epidemiological studies of **mortality** and **morbidity** show associations primarily with particles indoors generated outdoors.
- Poor correlations were found between ambient PM2.5 and personal exposure
- Is the ambient PM the most representative measure for exposure to PM?
- Health effects of indoor generated particles insufficiently documented



WHO – causes of death

Exception: Pollution from unvented burning of biofuels

Riley et al., ES&T 2002; Chen & Zhao, Atmos Environ, 2011

WHO on Household Air Pollution

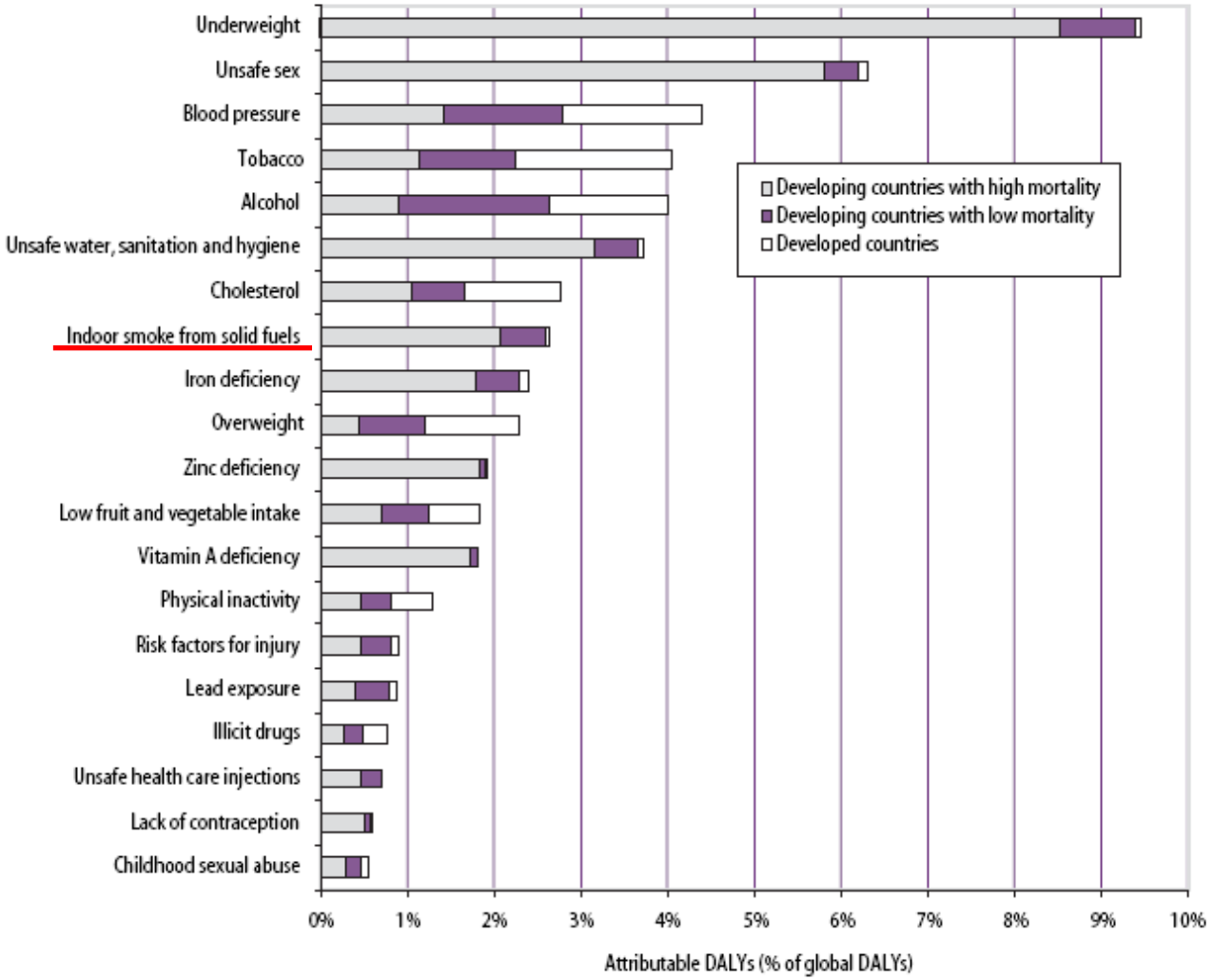
Globally in 2012

- Household Air Pollution from cooking with unclean fuels … caused 4.3 million deaths
- Outdoor air pollution caused 3 million deaths
- Among children under 5, Household Air Pollution estimated to cause half of all pneumonia deaths

World Health Statistics: 2016, Mortality due to air pollution by disease type, p. 75

Unvented biomass burning – Developing countries

Figure 4.9 Global distribution of burden of disease attributable to 20 leading selected risk factors



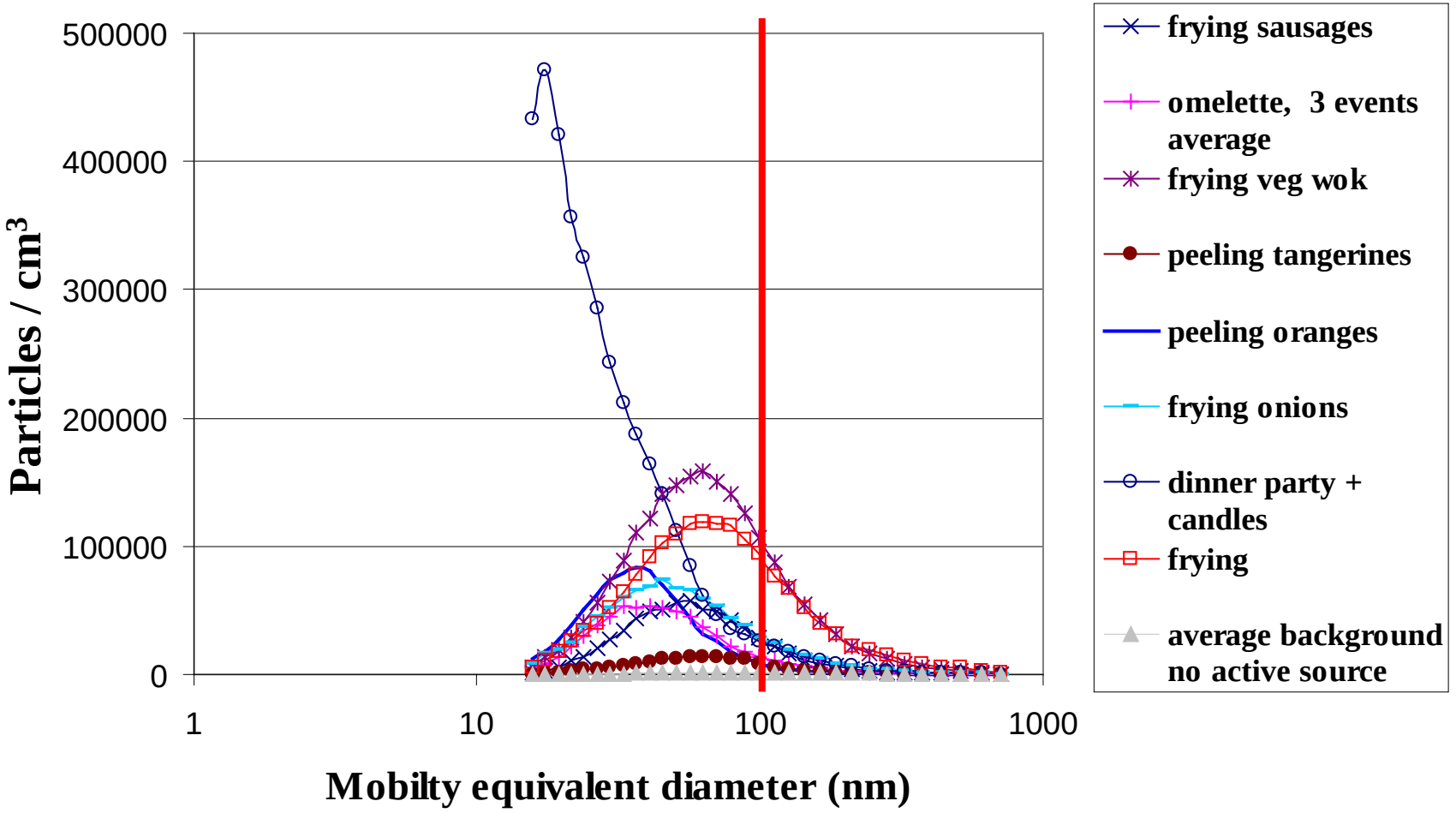
Sources of ultrafine particles

Outdoor sources

Indoor sources

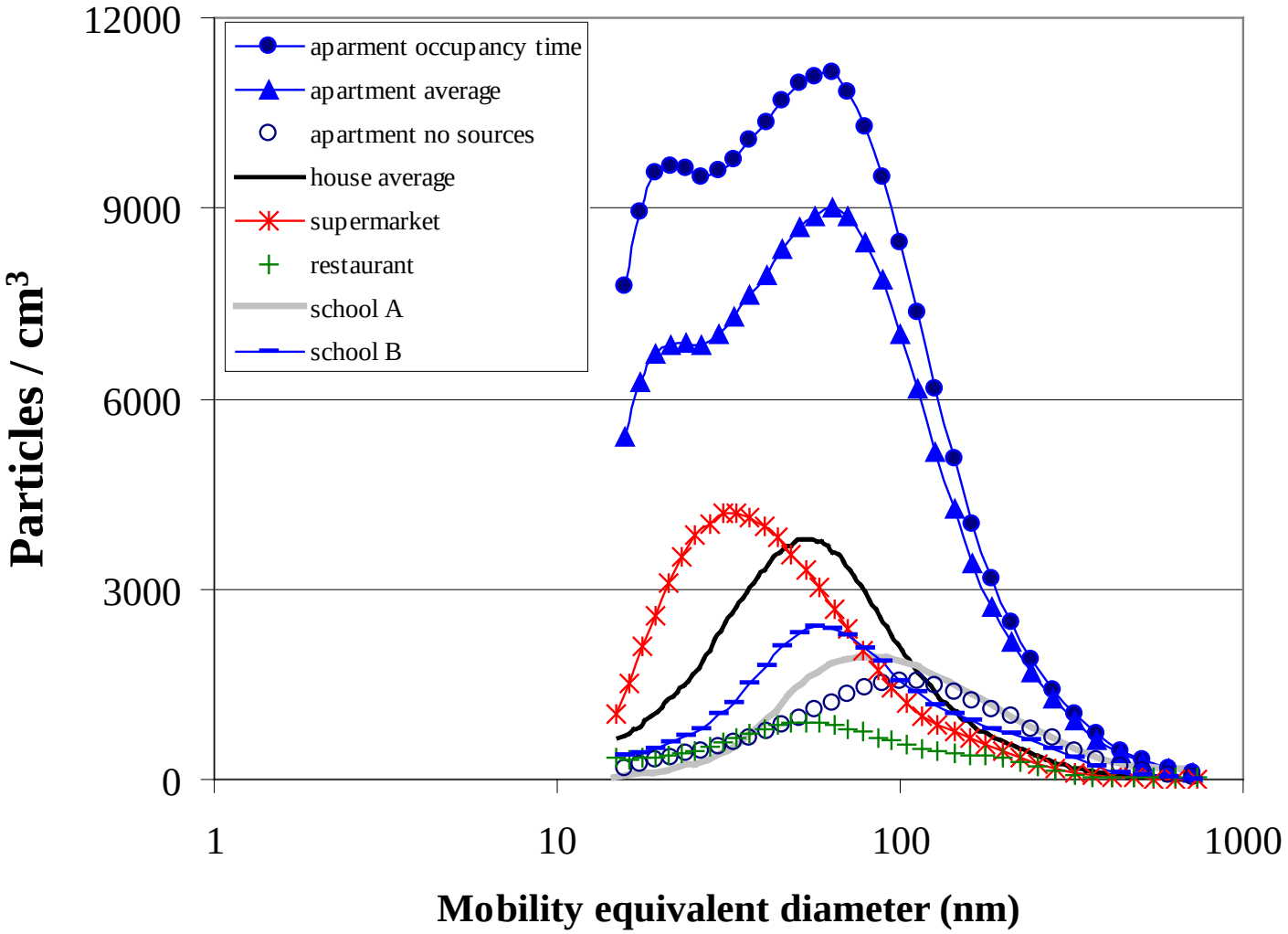
Which one do we inhale more of?

Number size distribution at peak concentrations from different activities in the apartment



Courtesy: A. Wierzbicka, Lund U.

Average number size distributions for various indoor environments

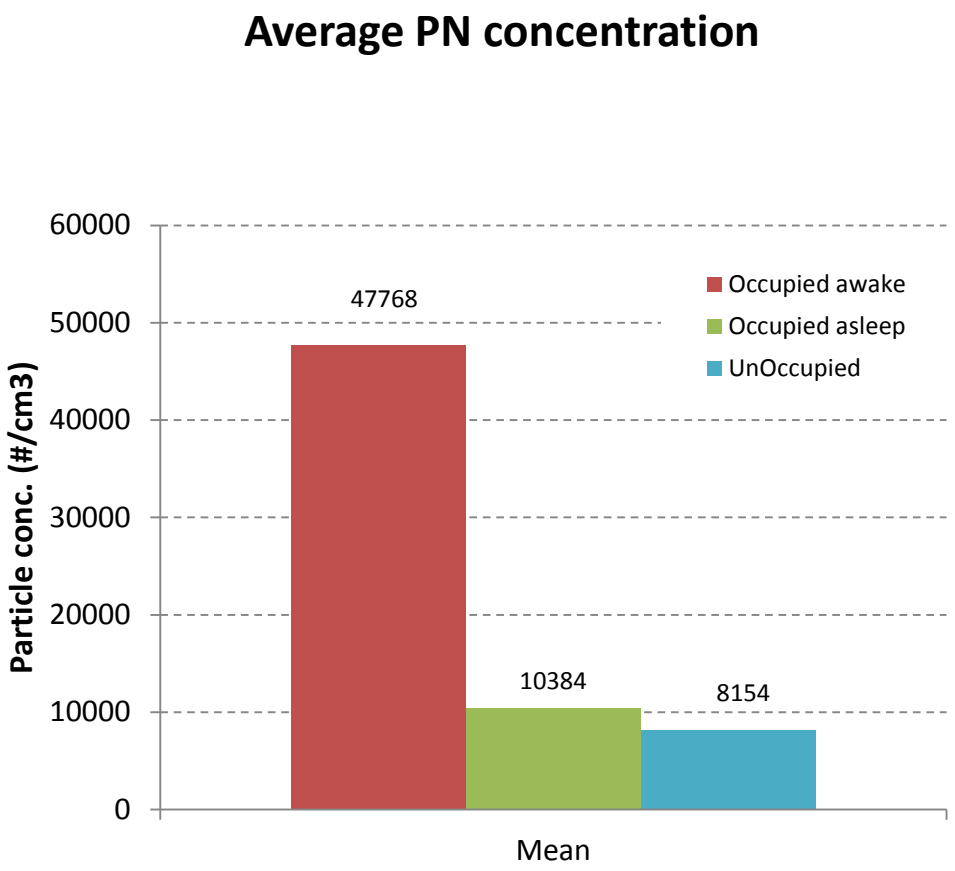


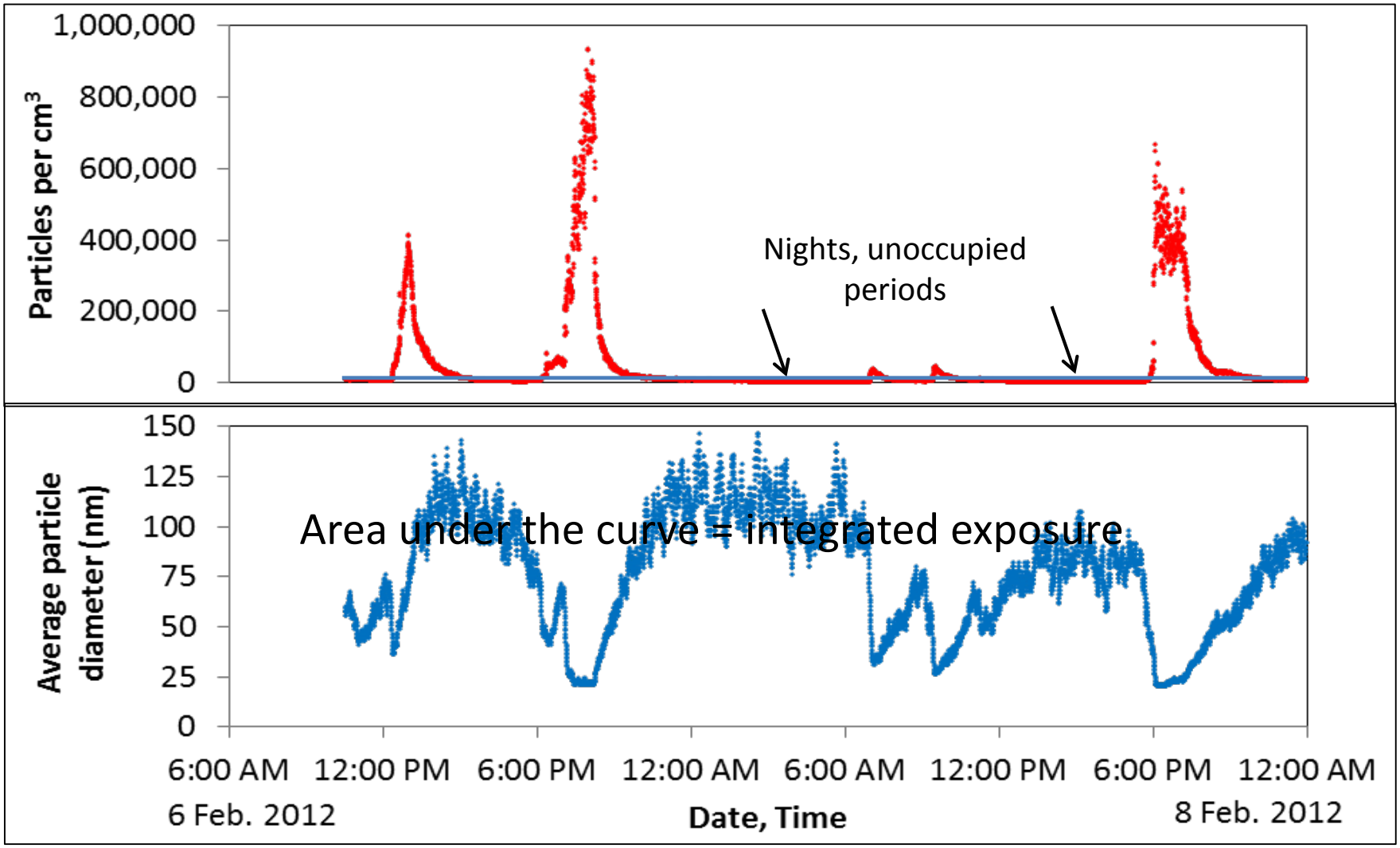
Courtesy: A. Wierzbicka, Lund U.

Measurements in 56 Copenhagen homes

- Inspection, Questionnaires
- CO_2, T, RH in bedroom and living room
- 2-weeks collection of settled dust on EDC for endotoxin, bacteria, mold and fungi
- **48-hour measurement of UFPs (10-300nm) in living room**

Occupancy

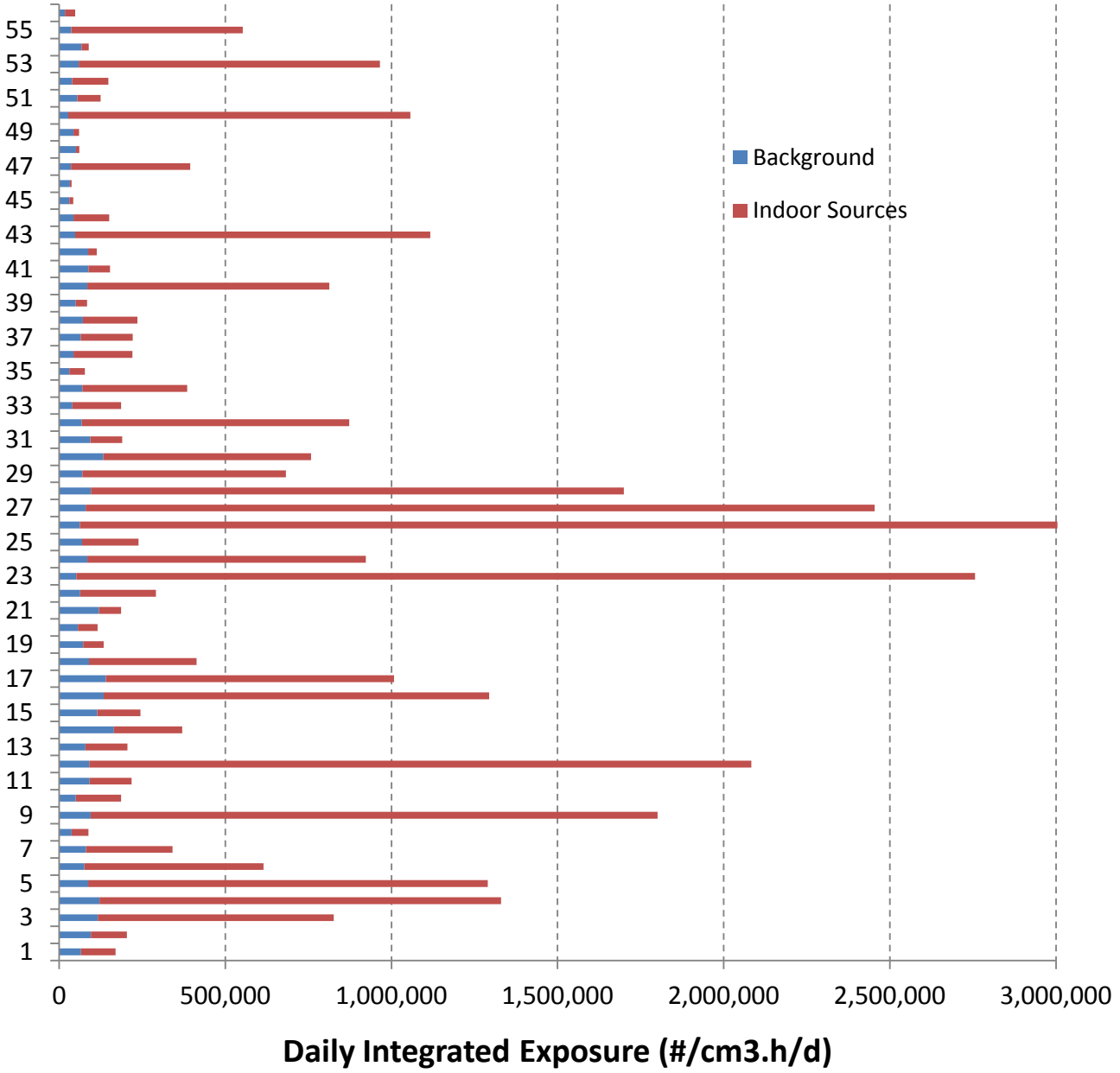

Average PN concentration
60000
50000
40000
30000
20000
10000
0
Particle conc. (#/cm3)
47768
10384
8154
Occupied awake
Occupied asleep
UnOccupied
Mean


1,000,000
800,000
600,000
400,000
200,000
0
Particles per cm³
Nights, unoccupied periods
150
125
100
75
50
25
0
Average particle diameter (nm)
Area under the curve = integrated exposure
6:00 AM
12:00 PM
6:00 PM
12:00 AM
6:00 AM
12:00 PM
6:00 PM
12:00 AM
6 Feb. 2012
Date, Time
8 Feb. 2012

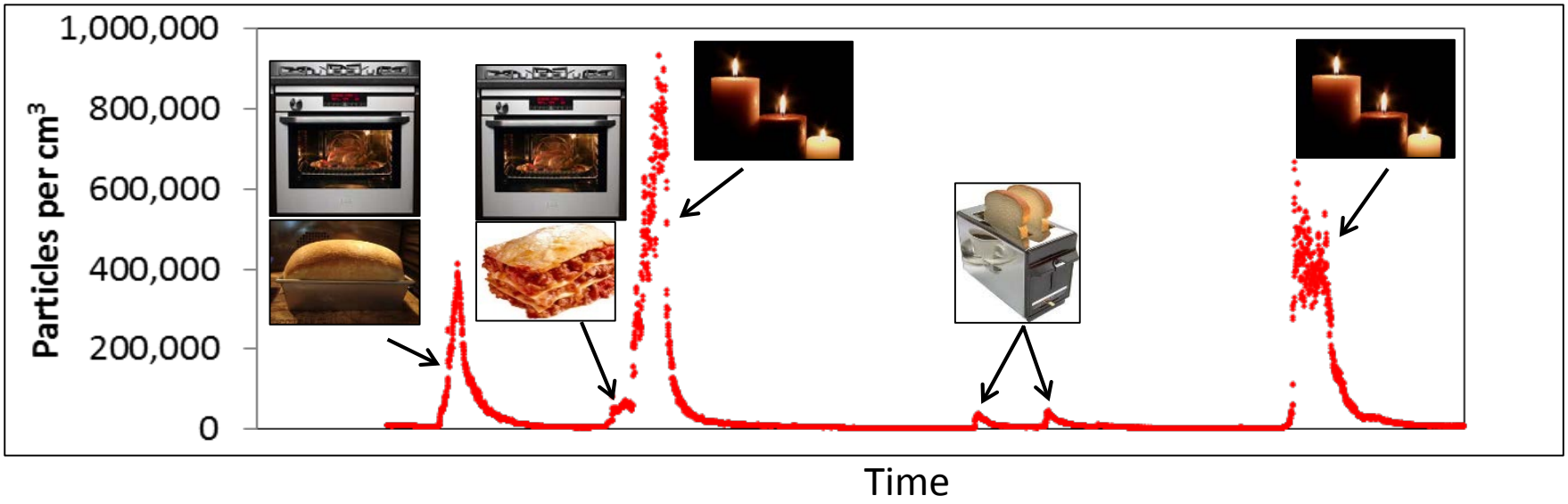
Contribution of background and indoor sources

Indoor sources explain about 65% of the total daily residential exposure

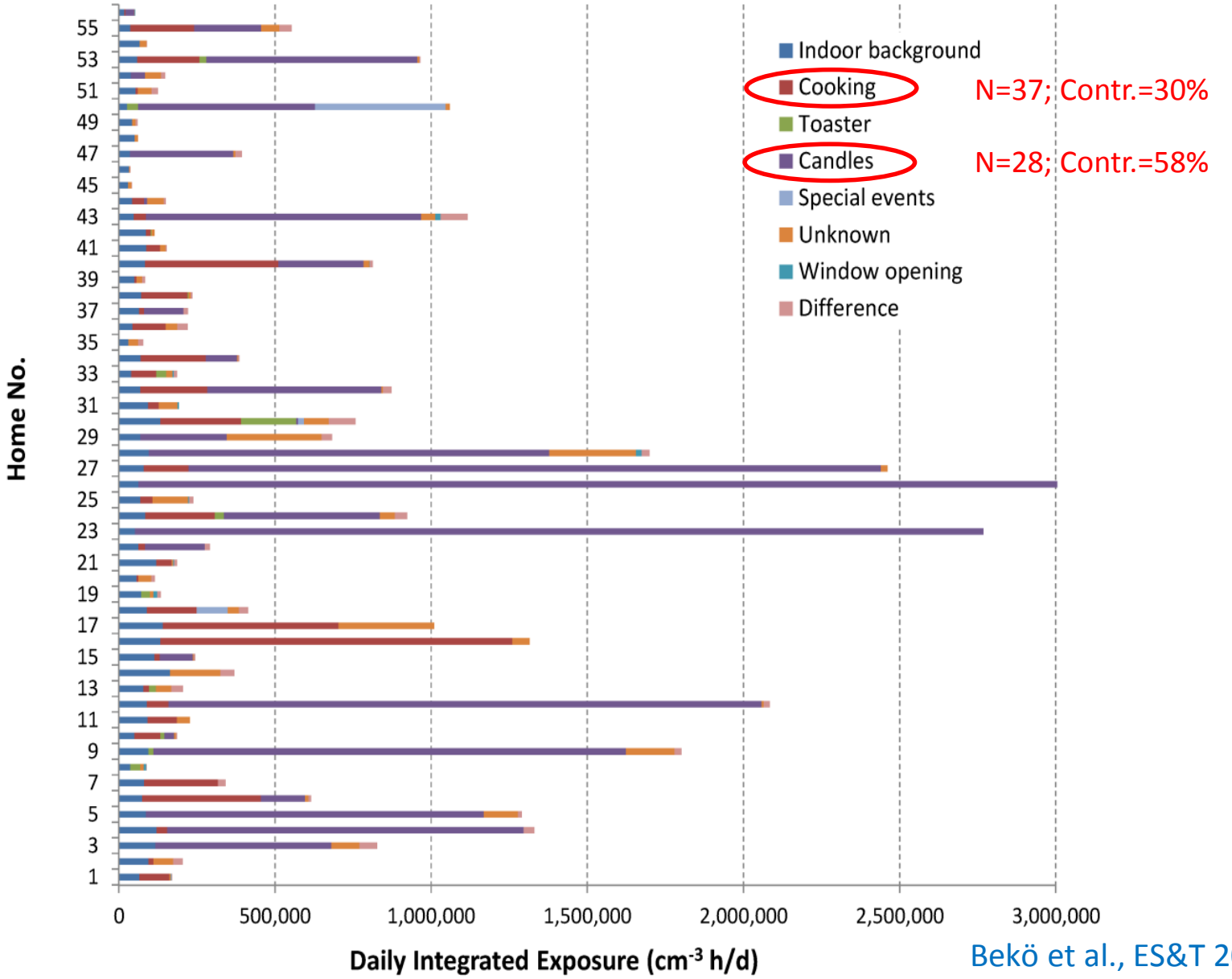
Contribution of indoor sources (%)	Location
59	USA
19 - 42	Beijing
47	USA
50-80	USA
58-69	Canada
66	Sweden
65	**Denmark**



Apportionment



Contribution of peaks/events



Bekö et al., ES&T 2013

Candle burning

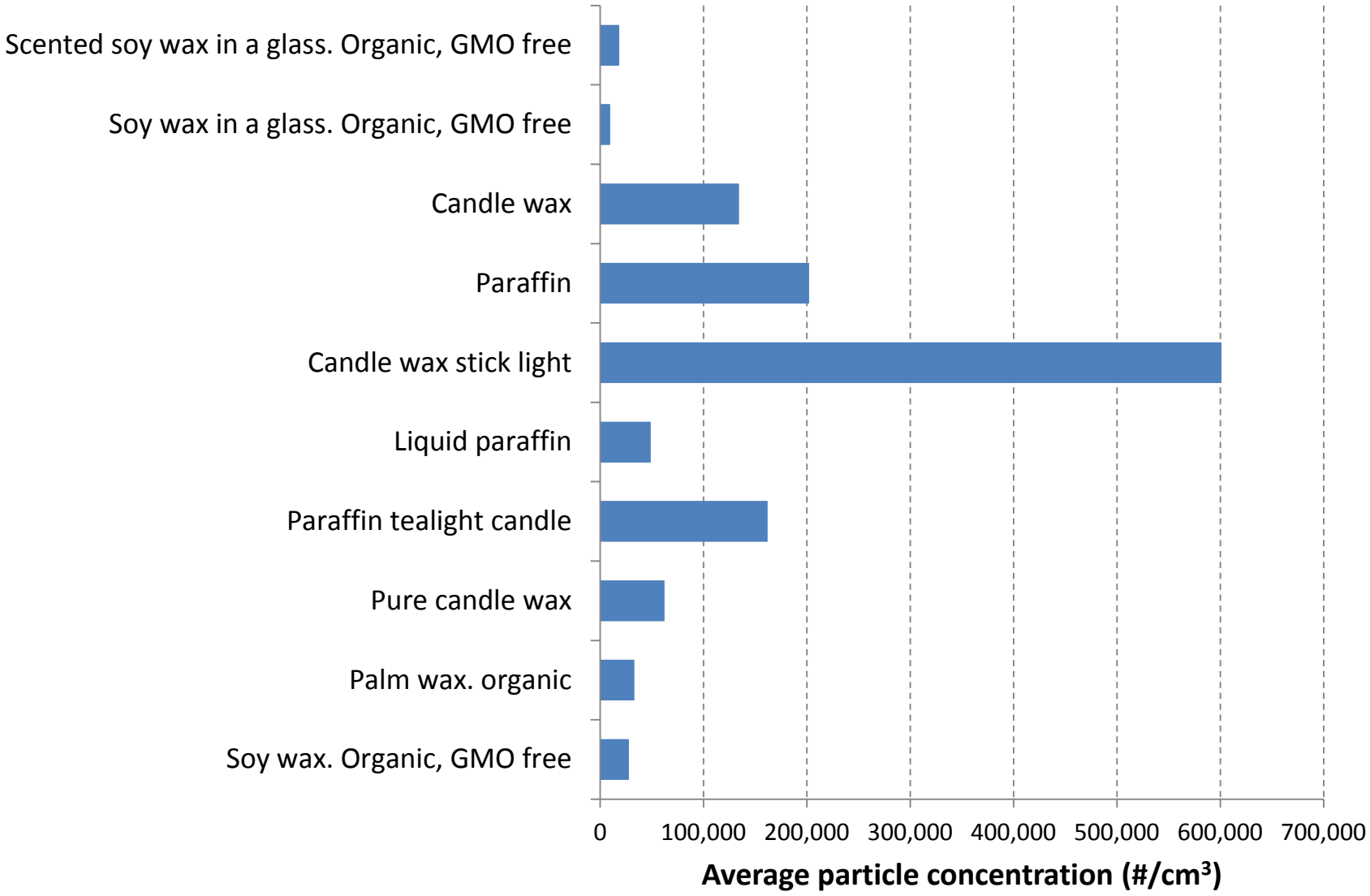
Occurring in 50% of homes, on average 5 times a week,
2.3 hours a day

Causing elevated PN levels on average over 5.7 hours per day,
8.2 hours after a candle event.

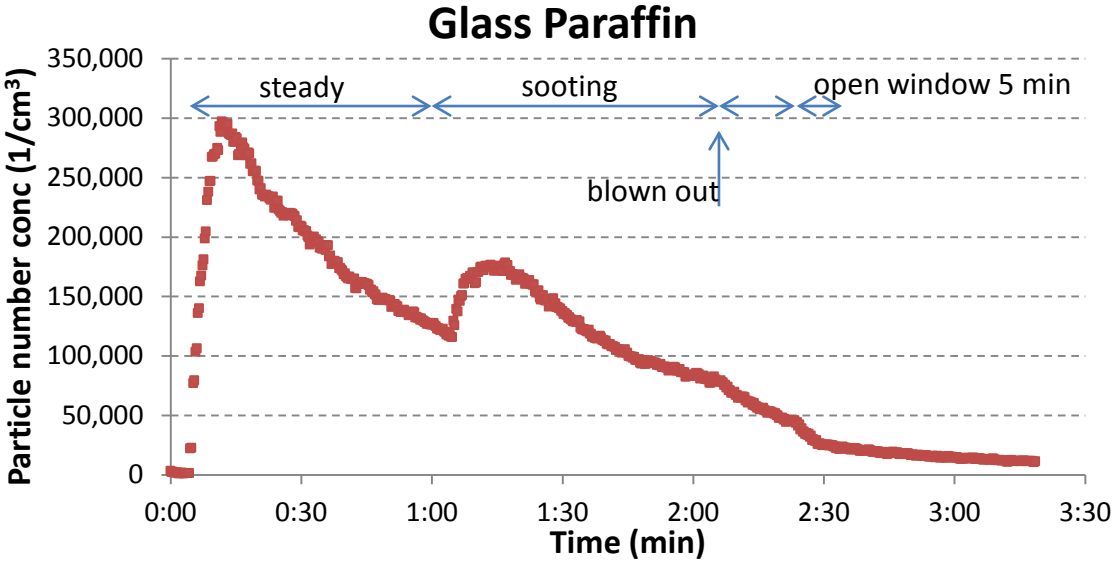
Responsible for 70% of the total exposure from indoor sources

60% of total residential exposure (incl. background from outdoor sources)

UFP from candles

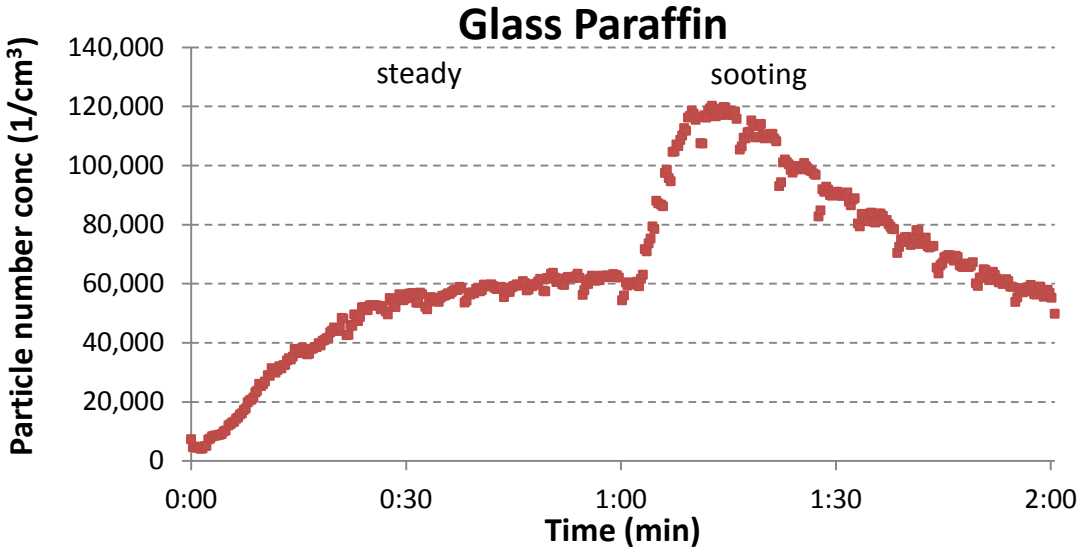


UFP from candles

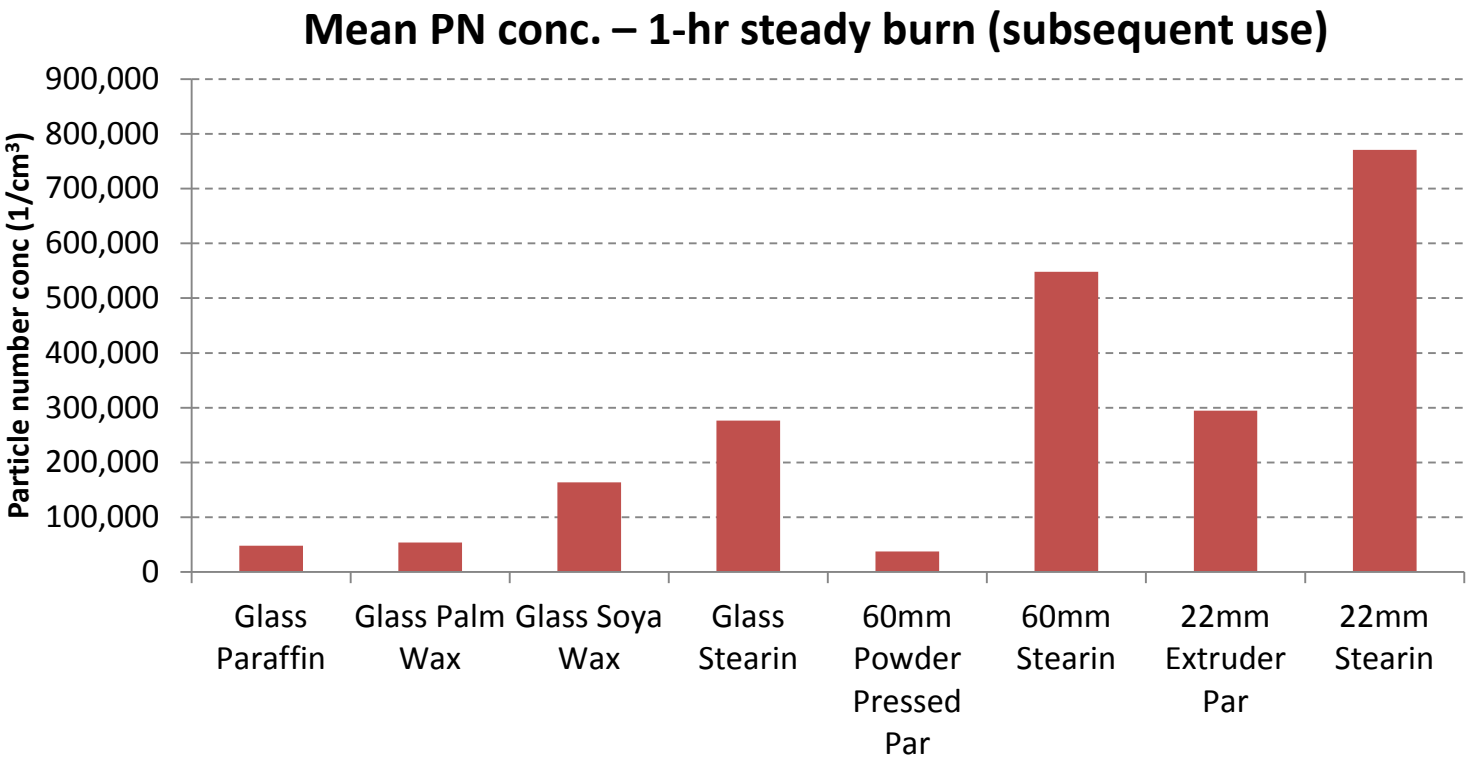


first time use

subsequent use



UFP from candles

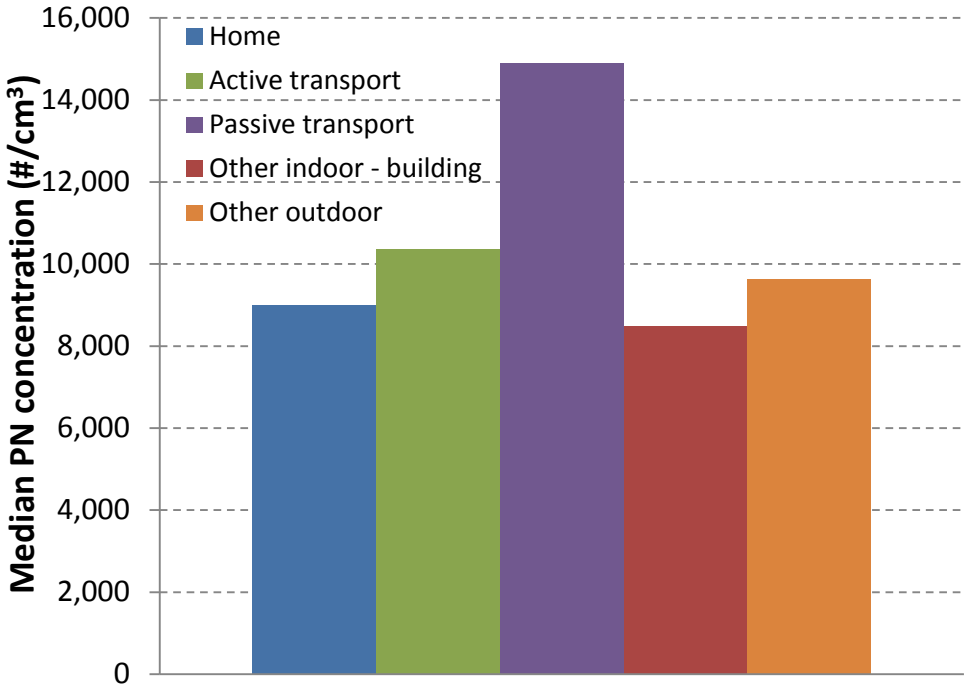


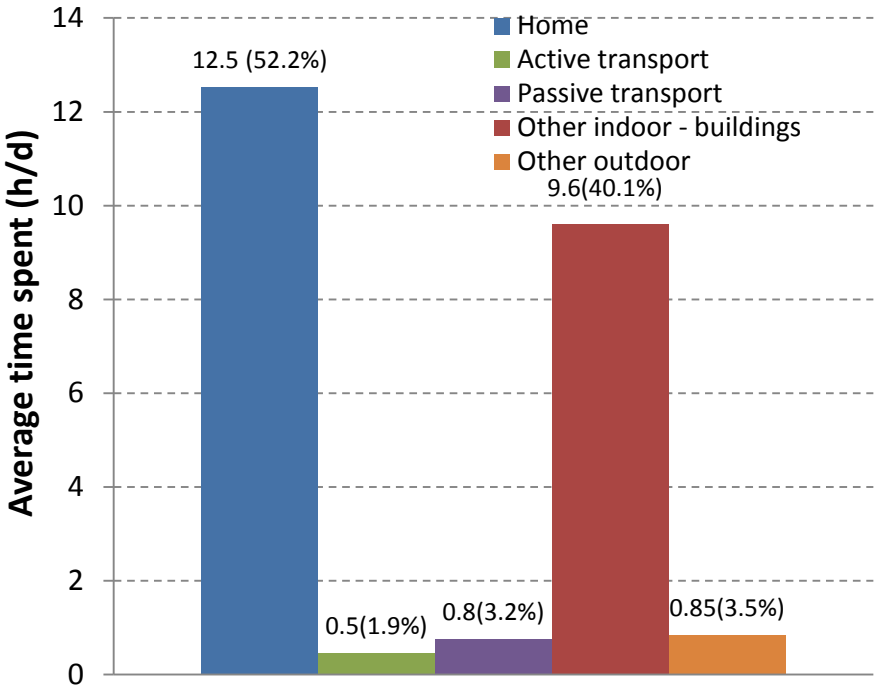
Measurements in 60 homes / 59 occupants

- Inspection, Questionnaires
- CO_2, T, RH in bedroom and living room
- 48-hour measurement of UFPs (10-300nm) in living room
- **Personal monitoring of UFP exposure + GPS**

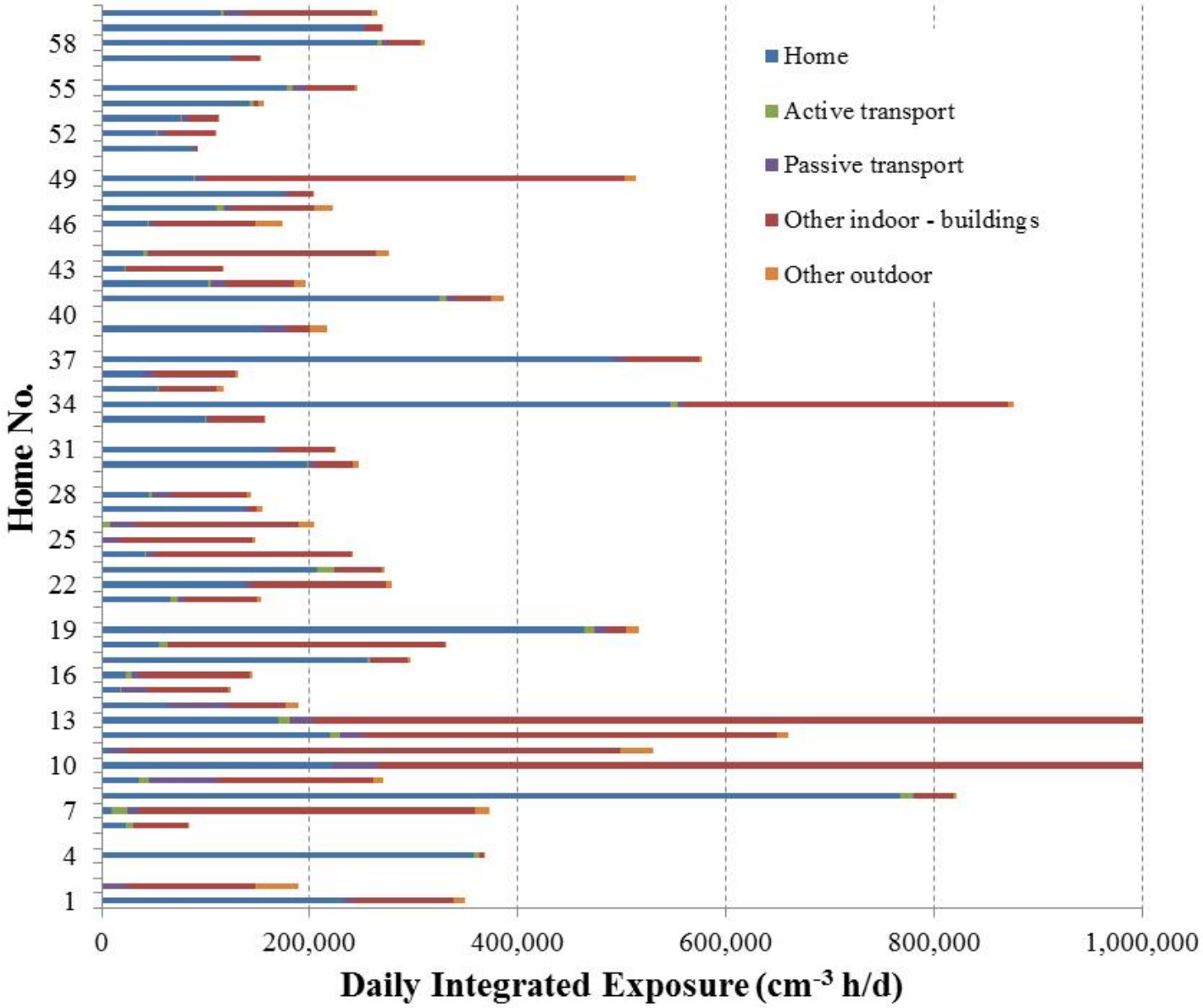
Personal monitor with GPS

Concentration x Time





Contribution of microenvironments



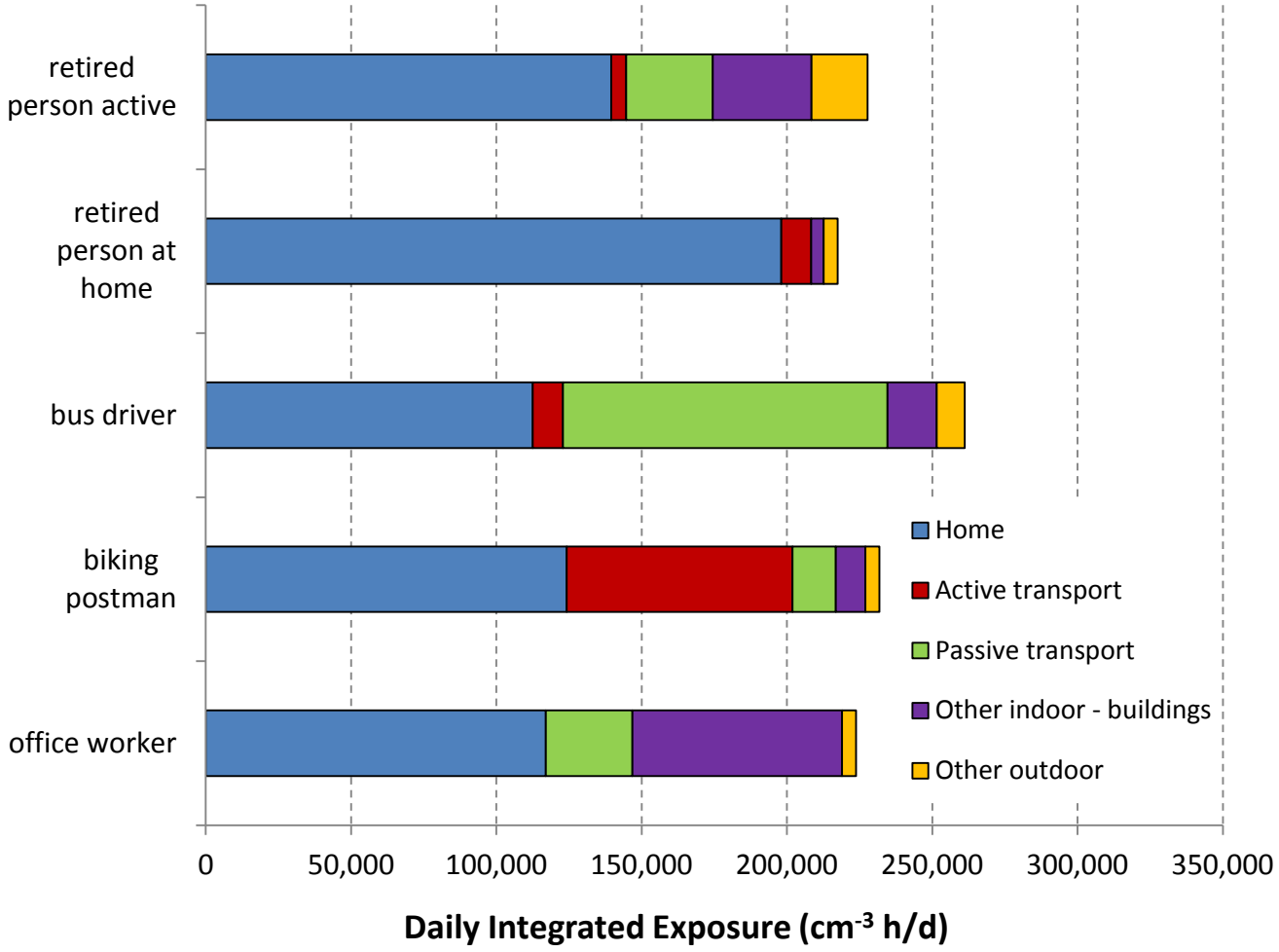
Where do we get most of it from?

~50% of total exposure occurs in the home

Location	*Median contrib. to total (%)*
In the home	***50***
Away from home	*50*
Active transport	*1.8*
Passive transport	*5.4*
Other indoor - buildings	*41.5*
Other outdoor	*3.3*
All indoors – buildings	*90.6*
All indoors incl. passive trans.	*95.4*
All outdoors	*4.6*

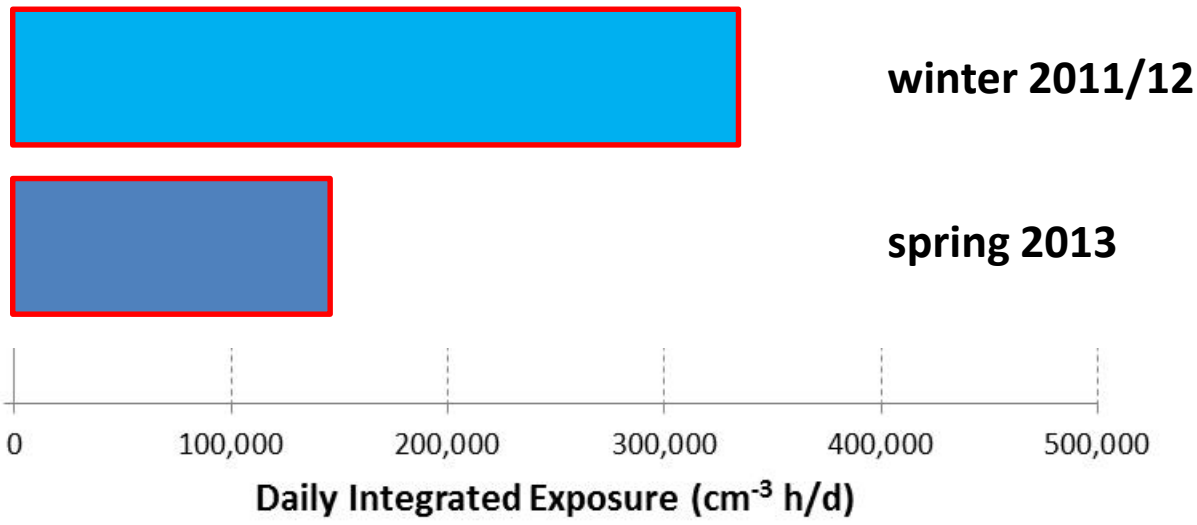
Bekö et al., Atm Env 2015

Where do YOU inhale most of it during the day?



The role of home

Average exposure within the home



Lung function and systemic effects

- Microvascular function, Lung function (FVC, FEV1), Biomarkers (inflammation; blood, urine, saliva)

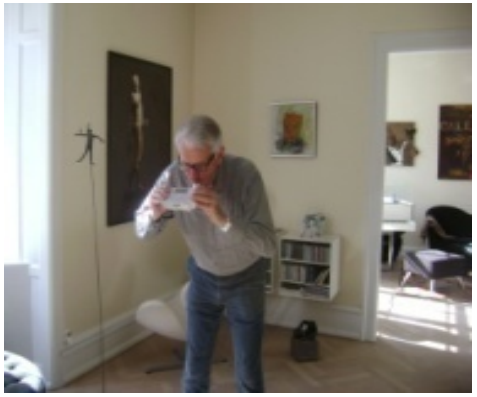
Winter 2012

- Association between residential exposure and lung function, markers of inflammation and diabetes

- When stratified, association confirmed for candle related exposure, not for cooking related exposure

Spring 2013

- Exposure outside the home (but not in the home) associated with microvascular function and markers of inflammation



- Traffic-generated UFP may be more potent regarding health effects than UFP from indoor sources

- Intervention (filtration) studies: conflicting results on the impact of **UFP** on microvascular function, lung function or biomarkers of inflammation

Summary & Recommendations for a healthier life

- A significant fraction (50%) of the total personal daily integrated exposure to UFP occurs within the home. Indoor sources significantly contribute to this exposure.
- Exposures indoors also dominate away from home. Outdoor sources may be responsible for a large fraction of this exposure.
- Outdoor particles may have more health effects than indoor generated particles, but **Indoor UFP are likely to have important adverse effects.**

- Never leave your home!
- Stop that cooking frenzy – grab fast food!
- Remember that not all winter days are Christmas days!
- Remember to ventilate, esp. when indoor sources are present!

Thank you!